



Noninvasive ventilation during the weaning process in chronically critically ill patients

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ABSTRACT Chronically critically ill patients often undergo prolonged mechanical ventilation. The role of noninvasive ventilation (NIV) during weaning of these patients remains unclear. The aim of this study was to determine the value of NIV and whether a parameter can predict the need for NIV in chronically critically ill patients during the weaning process.

We conducted a prospective study that included chronically critically ill patients admitted to Spanish respiratory care units. The weaning method used consisted of progressive periods of spontaneous breathing trials. Patients were transferred to NIV when it proved impossible to increase the duration of spontaneous breathing trials beyond 18 h.

231 chronically critically ill patients were included in the study. 198 (85.71%) patients achieved weaning success (mean weaning time 25.45±16.71 days), of whom 40 (21.4%) needed NIV during the weaning process. The variable which predicted the need for NIV was arterial carbon dioxide tension at respiratory care unit admission (OR 1.08 (95% CI 1.01–1.15), $p=0.013$), with a cut-off point of 45.5 mmHg (sensitivity 0.76, specificity 0.67, positive predictive value 0.76, negative predictive value 0.97).

NIV is a useful tool during weaning in chronically critically ill patients. Hypercapnia despite mechanical ventilation at respiratory care unit admission is the main predictor of the need for NIV during weaning.



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NIV is a useful tool during weaning in chronic critically ill patients independent of their premorbid condition <http://ow.ly/j4Av304sEoJ>



Introduction

Progress in the treatment of acute critical episodes has resulted in higher survival rates for patients admitted to intensive care units (ICU). However, these advances have also given rise to the appearance of a growing population characterised by prolonged dependence on mechanical ventilation (MV), requiring a tracheostomy and other life sustaining therapies [1]. These patients, known as chronically critically ill patients, represent up to 14% of patients admitted to ICUs for invasive MV, have an increased risk of in-hospital morbidity and mortality, and account for >37% of ICU costs [2]. For these reasons they are often transferred to specialised weaning units with multidisciplinary teams, which can offer advanced weaning protocols, a more comfortable environment for the patients and their families, and lower healthcare costs in comparison with ICUs [3, 4].

The two most common weaning methods used with patients with prolonged MV are pressure support ventilation and spontaneous breathing trials (SBT) [3]. Recently, JUBRAN *et al.* [5] have found that the use of SBT with a tracheostomy collar results in a shorter median weaning time, but with no effect on survival at 6 and 12 months. Noninvasive ventilation (NIV) has demonstrated its utility in shortening the MV weaning time in stable patients recovering from an episode of acute respiratory failure who had previously failed a conventional weaning trial [6]. It has been found to be able to reduce rates of death and pneumonia without increasing the risk of weaning failure, mainly in patients with chronic obstructive pulmonary disease (COPD) [6, 7]. The use of NIV for patients with prolonged MV has also been considered, but the number of studies addressing this question is limited and mainly focus on patients with COPD [8–10].

The aim of this study was to determine the role of NIV during weaning in chronically critically ill patients with prolonged MV and whether a clinical or functional parameter can predict the need for NIV in chronically critically ill patients during the weaning process.

Materials and methods

This is a multicentre prospective study that was conducted in the respiratory care units affiliated to the Spanish Respiratory Society. It included those chronically critically ill patients with prolonged MV admitted to these respiratory care units from ICUs between December 2013 and December 2014. A chronically critically ill patient was defined as one who has survived an acute critical illness or injury but had not yet recovered to the point of liberation from life sustaining therapies [1]. Prolonged MV was defined, in accordance with the National Association for Medical Direction on Respiratory Care recommendations, as those patients who need MV for >6 h·day⁻¹ for >21 consecutive days [11]. Informed consent was obtained from every patient and the protocol was approved by the ethics committees of the different hospitals. Exclusion criteria were refusal to participate in the study and irreversible neuromuscular disease in patients who develop ventilatory failure as a consequence of the neuromuscular process and who were candidates for long-term MV at home [1].

Data collection

The following information was collected from each chronically critically ill patient admitted to the respiratory care units: age, sex, premorbid medical conditions and premorbid medical status as measured by the Charlson comorbidity index [12], medical diagnosis which precipitated the critical event, duration of ICU stay, and duration of MV in the ICU. At the time of admission to the respiratory care unit, data regarding blood chemistry, blood gas, the presence of critical illness polyneuropathy/myopathy and the Acute Physiology and Chronic Health Evaluation (APACHE) II [13] were recorded.

Weaning protocol

At respiratory care unit admission, the tracheostomy tube was changed to one which was cuffed, fenestrated and had an inner cannula, and MV was established in pressure support ventilation. The level of positive end expiratory pressure was 4–6 cmH₂O and pressure support was set in order to achieve a tidal volume of 8 mL·kg⁻¹ of predicted body weight. The back-up rate was set at 12–18 breaths·min⁻¹ and trigger sensitivity was set at –1 cmH₂O. The ventilator settings were then readjusted for patient comfort and taking arterial blood gas values into account, in order to attempt to maintain arterial carbon dioxide tension (*P*_aCO₂) <45 mmHg. Inspiratory oxygen fraction (*F*_IO₂) was adjusted in order to maintain arterial oxygen saturation measured by pulse oximetry (*S*_pO₂) >90%. Bronchoscopy was performed in order to check the upper and lower airways for possible lesions related to intubation or tracheostomy tubes.

Over the following days, SBT was performed. During the SBT, the cuff of the tracheostomy tube was deflated and a fenestrated inner cannula was used. A heat and moisture exchanger with oxygen was placed at the top of the tracheostomy tube in order to maintain *S*_pO₂ >92%. The frequency and duration of SBT was increased progressively over the following days according to patient tolerance. SBT was interrupted

and MV was initiated and maintained for the remainder of the 24-h period if the patient presented with at least one of following: agitation; diaphoresis; depressed mental status; cyanosis; dyspnoea; accessory muscle activity; $SpO_2 < 90\%$; respiratory rate > 35 breaths·min⁻¹ or increased by 50%; heart rate > 140 beats·min⁻¹ or increased by 20%; systolic blood pressure > 180 mmHg or increased by 20%; systolic blood pressure < 90 mmHg; or cardiac arrhythmia. Once the patient was able to maintain spontaneous ventilation for 24 h the tracheostomy tube was replaced by one which was uncuffed and fenestrated, and a cap was placed at the top of the tracheostomy tube. When the patient was able to maintain adequate ventilation with the capped tracheostomy tube and was able to expel respiratory secretions by coughing, the tracheostomy tube was removed and the tracheostomy closed.

Those patients whose weaning process could not be completed due to the need for MV during the night were transferred to NIV. The criterion for transfer to NIV was when it proved impossible to increase the duration of SBT beyond 18 h during five consecutive days [5]. Two different techniques were used to affect the transfer to NIV. In some respiratory care units, the tracheostomy was replaced by a tracheal button and NIV was initiated; in others, NIV was applied with the tracheostomy tube having been capped, its cuff deflated and using a fenestrated inner cannula. In both cases, NIV was applied through a nasal or oronasal mask in pressure support mode and with oxygen added if necessary. The ventilator was initially set up so as to attain a tidal volume of ~ 8 – 10 mL·Kg⁻¹. The back-up respiratory rate was set at 12–16 breaths·min⁻¹ and the inspiratory trigger sensitivity at -1 cmH₂O. The ventilatory parameters were then readjusted in order to achieve effective ventilation ($P_{aCO_2} < 45$ mmHg and time spent with $SpO_2 < 90\%$ at night using NIV $< 5\%$). Once NIV was tolerated by the patient and effective ventilation had been achieved the tracheal button or tracheostomy tube was removed and the tracheostomy was closed.

Patient management

During the stay in the respiratory care unit all patients were continuously monitored *via* pulse oximetry and electrocardiography. Possible factors that could interfere with the weaning process were identified and treated. Patients received physical therapy for critical illness polyneuropathy/myopathy and any complications arising during the respiratory care unit stay were treated. Respiratory secretions were managed with tracheal suctioning with a conventional catheter *via* the tracheostomy tube three times a day or when necessary (dyspnoea, sense of retained secretions, decreased SpO_2 or decreased tidal volume during MV).

Outcomes

Weaning was considered to have been a success when complete liberation from MV occurred or only nocturnal NIV was required for seven consecutive days [11]. Time to weaning success, length of stay at the RCU, in-hospital survival and destination after respiratory care unit discharge were recorded, as well as 1-year survival.

Statistical analysis

Data were expressed as mean \pm SD for continuous normally distributed variables, median (interquartile range) for not normal distributed variables and as frequency counts and percentages for binary and categorical variables. Data comparisons were performed using Student's t-test and the Mann-Whitney test for normally and not normally distributed data, respectively; categorical data were compared using the Chi-squares test. Forward stepwise logistic regression analysis was performed to determine those variables which were independently associated with the need for NIV in order to achieve weaning success. Variables were first examined using univariate analysis; those variables that exhibited a significant association in the previous univariate analysis ($p < 0.2$) were included in the multivariable model. Receiver operating characteristic curves were used to identify a cut-off point for those variables that best predicted the patients for whom NIV was able to play a role during the weaning process. Statistical significance was taken as $p < 0.05$.

Results

During the period of the study 4609 patients were admitted to different respiratory care units, of whom 231 patients were chronically critically ill, were referred due to prolonged MV and were then enrolled. Table 1 shows the main demographic and clinical data for patients at respiratory care unit admission. The main premorbid medical conditions were hypertension (48.9%), diabetes mellitus (22.5%), congestive heart failure (19%) and COPD (18.6%). 84 (36.4%) patients were current smokers. The main acute illnesses resulting in chronic critical illness were community acquired pneumonia ($n=30$ (13%)), cardiac valve replacement surgery ($n=19$ (8.2%)), thoracic surgery ($n=12$ (5.2%)) and neurosurgery ($n=11$ (4.8%)).

The mean respiratory care unit stay was 56.99 ± 40.52 days. 29 (12.6%) patients died during their stay at the respiratory care unit. 198 (85.71%) patients achieved weaning success and the mean weaning time was

25.45±16.71 days. At respiratory care unit discharge, patients presented with pH 7.42±0.03, arterial oxygen tension 80.31±17.02 mmHg, P_{aCO_2} 41.01±5.35 mmHg and F_{iO_2} 0.21±0.01. Four (1.7%) patients were discharged at home with long-term MV *via* a tracheostomy tube due to it proving impossible to achieve weaning success. In one patient, after successful removal of MV, the tracheostomy could not be closed due to the lack of an effective cough for the removal of respiratory secretions. At the end of the respiratory care unit stay 149 (64.5%) patients were discharged to their homes, 17 (7.4%) patients were transferred to other hospital departments (mainly thoracic surgery and respiratory medicine departments), and 36 (15.6%) patients were transferred to long-term facilities in order to continue with specific physical therapy for their critical illness polyneuropathy/myopathy. After respiratory care unit discharge 32% of the patients died during the first year.

Among patients who achieved weaning success, 40 (21.4%) patients needed NIV during the weaning process. Statistical differences were found between patients who needed NIV and those who did not in APACHE II, the critical illness triggering the chronic critical illness and P_{aCO_2} at respiratory care unit admission (tables 1 and 2). Regarding premorbid medical conditions, differences were found between the NIV group and those who did not require NIV in the proportions of patients with obstructive sleep apnoea syndrome (12.8% *versus* 3.4%, $p=0.02$), congestive heart failure (30.8% *versus* 12.3%, $p=0.006$) and chronic renal failure (17.5% *versus* 4.1%, $p=0.003$). In the NIV group there were higher proportions of patients with home continuous positive airway pressure (10.3% *versus* 2.7%, $p=0.038$) and home NIV (7.7% *versus* 0.7%, $p=0.007$). No statistical differences were found between the NIV and non-NIV groups with regard to the proportion of patients with critical illness polyneuropathy/myopathy (72.7% *versus* 74.6%, $p=0.863$). At respiratory care unit discharge, all those patients in whom NIV had been employed during the weaning protocol were using long-term NIV (supplementary material).

The results of the univariate logistic regression analysis, carried out to establish which variables most accurately predicted the need for NIV during weaning, are shown in table 3. In the multivariate analysis, the only variable which predicted the need for NIV was P_{aCO_2} at respiratory care unit admission (OR 1.08 (95% CI 1.01–1.15), $p=0.013$). In the receiver operating characteristic curve analysis, the variable with the highest area under the curve was P_{aCO_2} at respiratory care unit admission (area under the curve 0.694 (95% CI 0.560–0.828), $p=0.008$). A cut-off point of 45.5 mmHg for P_{aCO_2} was the best predictor for the identification of the patients in whom NIV would become necessary during the weaning process (sensitivity 0.76, specificity 0.67, positive predictive value 0.76, negative predictive value 0.97).

TABLE 1 Demographic and clinical data of the 231 chronically critically ill patients at admission to the respiratory care unit

	Patients
Male/female	149/82
Age years	62.76±15.03
Medical/surgical cause of critical illness	130/101
Charlson index	1.73±1.74
APACHE II	12.49±5.34
Intensive care stay days	44.72±23.05
Mechanical ventilation in intensive care days	36.74±23.93
pH	7.35±0.14
P_{aO_2} mmHg	97.09±49.78
P_{aCO_2} mmHg	46.65±9.44
F_{iO_2}	0.43±0.16
Leukocytes per L	10 152.78±3612.81
Neutrophils %	75.42±11.57
Haemoglobin g·dL ⁻¹	9.66±1.49
Haematocrit %	29.21±4.57
Platelets per L	291 278.35±0.01
Sodium mmol·L ⁻¹	138.73±5.50
Potassium mmol·L ⁻¹	4.03±0.52
Blood urea nitrogen mg·dL ⁻¹	52.46±38.98
Creatinine mg·dL ⁻¹	0.76±0.56
Serum albumin g·dL ⁻¹	3.05±0.57
C-reactive protein mg·L ⁻¹	50.92±49.63

Data are presented as n or mean±sd. APACHE: Acute Physiology and Chronic Health Evaluation; P_{aO_2} : arterial oxygen tension; P_{aCO_2} : arterial carbon dioxide tension; F_{iO_2} : inspiratory oxygen fraction.

TABLE 2 Demographic and clinical data of the chronically critically ill patients who achieved weaning success at respiratory care unit admission

	NIV	No NIV	p-value
Subjects	40	158	
Male/female	21/19	108/50	0.158
Age years	64.74±13.78	60.99±15.52	0.780
Medical/surgical cause of critical illness	30/10	87/71	0.048
Charlson index	1.97±1.34	1.45±1.61	0.153
APACHE II	14.00±3.55	11.81±5.51	0.037
Intensive care stay days	43.25±20.32	40.40±29.75	0.850
Mechanical ventilation in intensive care days	34.81±18.45	35.96±20.69	0.606
Respiratory care unit stay days	58.97±38.09	51.73±31.20	0.275
Weaning time at respiratory care unit days	29.00±17.56	23.77±16.42	0.211
1-year mortality %	12.1	12.8	0.876
Pressure support on mechanical ventilation cmH₂O	20.34±1.03	21±0.92	0.876
PEEP cmH₂O	4.32±0.01	4.93±0.02	0.765
Back-up respiratory rate on mechanical ventilation breaths·min⁻¹	13.21±0.93	14.01±0.23	0.854
pH	7.38±0.06	7.35±0.09	0.055
P_aO₂ mmHg	94.87±27.76	99.31±61.46	0.628
P_aCO₂ mmHg	50.32±10.33	43.95±8.56	0.004
F_iO₂	0.38±0.7	0.37±0.16	0.437
Leukocytes per L	9968.18±2685.28	10042.29±3832.71	0.975
Neutrophils %	72.05±12.53	75.92±11.12	0.233
Haemoglobin g·dL⁻¹	9.70±1.62	9.54±1.46	0.777
Haematocrit %	29.09±5.24	28.95±4.50	0.963
Platelets per L	284454.54±0.01	307065.57±0.01	0.461
Sodium mmol·L⁻¹	138.86±5.87	138.36±4.53	0.763
Potassium mmol·L⁻¹	4.10±0.54	4.03±0.56	0.476
Blood urea nitrogen mg·dL⁻¹	55.86±49.58	47.90±30.17	0.512
Creatinine mg·dL⁻¹	0.84±0.76	0.70±0.45	0.443
Serum albumin g·dL⁻¹	3.10±0.65	3.02±0.55	0.550
C-reactive protein mg·L⁻¹	38.06±39.70	57.12±54.38	0.132

Data are presented as n or mean±SD, unless otherwise stated. NIV: noninvasive ventilation; APACHE: Acute Physiology and Chronic Health Evaluation; PEEP: positive end expiratory pressure; P_aO₂: arterial oxygen tension; P_aCO₂: arterial carbon dioxide tension; F_iO₂: inspiratory oxygen fraction.

Discussion

The findings of the present study show that NIV is a useful tool during the weaning process in patients with chronic critical illness, regardless of their premorbid medical conditions. Moreover, chronically critically ill patients with hypercapnia despite MV at respiratory care unit admission could benefit from NIV with regard to achieving successful weaning.

Chronic critical illness represents a syndrome that is mediated by the host's systemic inflammatory response and is characterised by prolonged MV, profound muscle weakness, neuroendocrine changes, nutritional deficiencies, increased vulnerability to infection, brain dysfunction and skin breakdown [1]. The results of the present study are consistent with recent epidemiological studies [14, 15] showing a chronically critical ill population with a mean age of ~62 years with several comorbid conditions. The mean Charlson comorbidity index score of our patients (1.73±1.74) is similar to that reported by previous authors [15]. Our patients presented prolonged ICU stays, with a mean duration of MV in the ICU of 36.74±23.93 days. Patient's mortality in the present study during the respiratory care unit stay (12.6%) is similar to previous studies [8, 10, 16, 17]. We used SBT as the weaning method, which has recently been found to be the method which achieves weaning success in the shortest time in patients with prolonged MV. Our results show a weaning success rate of 87.5% with a median weaning time from respiratory care unit admission of 21 days. Across all the studies that report successful liberation from MV in chronic critical illness, the rate of weaning success is 57% (95% CI 55–60) [18]. Similar results to ours regarding weaning success have been reported previously [8, 19, 20]. Reasons for this high rate could be due to: differences in definitions (chronic critical illness, prolonged MV, weaning success, *etc.*) or patient selection between the different previous studies; the use of an organised approach to weaning undertaken at the

TABLE 3 Predictors of need for noninvasive ventilation during weaning: univariate analysis

	OR (95% CI)	p-value
Male	0.570 (0.281–1.157)	0.119
Age years	1.018 (0.992–1.044)	0.173
Medical cause of critical illness	2.803 (1.278–6.147)	0.010
Charlson index	1.212 (0.977–1.502)	0.080
Tobacco	3.536 (1.469–8.512)	0.005
COPD	0.879 (0.364–2.125)	0.879
OSA	0.239 (0.066–0.874)	0.030
CHF	0.316 (0.137–0.733)	0.007
Ischaemic cardiopathy	0.369 (0.189–2.158)	0.470
Chronic renal failure	0.202 (0.064–0.641)	0.007
Neoplasm	1.263 (0.494–3.224)	0.626
Hypertension	0.861 (0.428–1.732)	0.674
Diabetes mellitus	1.543 (0.628–3.788)	0.344
Atrial fibrillation	3.750 (0.801–17.555)	0.093
Premorbid home CPAP	0.245 (0.058–1.027)	0.054
Premorbid home NIV	0.082 (0.008–0.814)	0.033
Apache II	1.082 (1.006–1.165)	0.035
Critical care stay	1.003 (0.990–1.017)	0.629
Mechanical ventilation duration at critical care	0.997 (0.972–1.023)	0.187
pH	30.29 (0.114–8056.41)	0.231
P_{aO_2}	0.998 (0.988–1.008)	0.735
P_{aCO_2}	1.078 (1.015–1.146)	0.015
F_{iO_2}	1.648 (0.050–54.064)	0.779
Leukocytes	1.00 (1.00–1.00)	0.933
Haematocrit	1.006 (0.906–1.118)	0.907
Platelets	1.00 (1.00–1.00)	0.483
Sodium	1.021 (0.925–1.128)	0.678
Potassium	1.249 (0.519–3.008)	0.619
Blood urea nitrogen	1.006 (0.993–1.018)	0.385
Creatinine	1.547 (0.673–3.556)	0.305
Serum albumin	1.306 (0.539–3.165)	0.555
C-reactive protein	0.991 (0.979–1.003)	0.144

COPD: chronic obstructive pulmonary disease; OSA: obstructive sleep apnoea; CHF: congestive heart failure; CPAP: continuous positive airway pressure; NIV: noninvasive ventilation; P_{aO_2} : arterial oxygen tension; P_{aCO_2} : arterial carbon dioxide tension; F_{iO_2} : inspiratory oxygen fraction.

specific and specialised units located in the acute hospital; and the use of multidisciplinary care and the utilisation of NIV in those patients with weaning failure. In fact, if those patients in whom NIV was used are excluded from the weaning success group, our weaning rate is 68%, which is more in line with the rates reported in other studies [18].

Despite weaning protocols, multidisciplinary approaches and specialised care, some patients remain ventilator-dependent and weaning success cannot be achieved. In such cases, NIV has been reported to be useful during the weaning process in patients with chronic critical illness [19, 21, 22]. Although there is lack of evidence supporting the effectiveness of NIV with chronically critically ill patients, NIV in this population is normally used for those patients who require only nocturnal ventilatory support. In the present study, 21.4% of the successful cases of weaning were achieved using NIV. Previous studies have specifically analysed the role of NIV in patients with prolonged MV [8, 9, 19]. In the study by SCHONHOFER *et al.* [9], 403 (28.81%) patients received NIV during the weaning process due to significant hypercapnia after 24 h of spontaneous breathing; 31.5% of the discharged patients continued using NIV during the night at home. The NIV group was younger, used MV for a shorter period and had lower APACHE II scores at admission. In a study focusing only on COPD patients with prolonged MV, QUINNELL *et al.* [8] applied criteria for NIV initiation very similar to ours. NIV was used during the weaning protocol with 59.70% of the patients included in the study [8]. Of those patients who used NIV 62% were discharged to their homes with long-term NIV. In a study of 117 COPD patients with prolonged weaning, HEINEMANN *et al.* [19] recorded 82 successfully weaned patients, 39 (47.6%) of whom required home NIV due to persistent chronic ventilatory failure. Home NIV was associated with a higher rate of survival after 1 year. In the present study, the NIV group had higher APACHE II scores and P_{aCO_2} at respiratory care unit admission and the critical cause triggering

chronically critical illness was a medical condition; moreover, patients with premonitory obstructive sleep apnoea, congestive heart failure and chronic renal failure were more likely to require NIV despite there being no differences in the Charlson comorbidity index, and this was also the case for those using continuous positive airway pressure or NIV previously at home. However, the only factor that we found that predicted the need for NIV during the weaning process was the presence of hypercapnia despite the use of MV at respiratory care unit admission. This finding suggests that, after the critical episode, these patients were probably in a worse thoracopulmonary condition, preventing them from achieving spontaneous breathing by themselves and therefore needing NIV in order for invasive MV to be removed. In this way, SELLARES *et al.* [23] have found that those patients with prolonged weaning presented with greater P_{aCO_2} under MV, although other studies did not find differences [24, 25].

Reported 1-year mortality for prolonged MV ranges between 40% and 75% [18], which is higher than in patients requiring short-term MV [26]. In prolonged MV patients, successful weaning does not ensure long-term survival; chronically critically ill patients have underlying comorbid conditions, residual organ dysfunction and intercurrent complications that increase the risk of death [27]. In fact, for prolonged MV, advanced age, poor previous functional status and residual organ failures have been reported to be associated with greater mortality [28, 29]. In the present study, 1-year mortality was found to be in the lower range of those reported previously [18]. This variability in survival reported by the different studies reflects differences in single centre patient selection, patient care practice and patient characteristics. Previous studies [8–10] have found home NIV after discharge to be a prognostic factor for long-term survival in chronically critically ill patients [8, 19]. However, our results do not demonstrate any difference in the rate of mortality at 1 year in relation with NIV.

The main limitation of the study is its observational design. Perhaps, over a longer period, these patients could have achieved weaning success without NIV, and so a randomised controlled trial would demonstrate the real value of NIV during the weaning of such patients. Another limitation concerns the different treatment approaches, mainly with regard to the two techniques that were used to affect the transfer to NIV, a capped tracheostomy tube and a tracheal button. We did not find differences between the two approaches although the presence of an intratracheal cannula can lead to an increase in airway resistance and work of breathing [30].

In conclusion, for those chronically critically ill patients managed at an respiratory care unit who present with $P_{aCO_2} >45$ mmHg after 24 h of spontaneous breathing or for whom it proves impossible to increase the duration of SBT beyond 18 h, the use of NIV can be a useful procedure with regard to achieving weaning success. The main predictor of the need for NIV during weaning in chronically critically ill patients is the presence of hypercapnia despite MV at respiratory care unit admission.

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